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Tactical Environmental Data Services (TEDServices) Post FBE-K Technical Execution Report

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This report reviews the technical execution of the Tactical Environmental Data Services (TEDServices) in the context of Fleet Battle Experiment-Kilo (FBE-K). The report includes a comprehensive description of TEDServices features executed in FBE-K. Also detailed are high-level TEDServices concepts and software components as well as operational concepts and specific data flow scenarios.

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TACTICAL ENVIRONMENTAL DATA SERVICES (TEDSERVICES) POST FBE-K TECHNICAL EXECUTION REPORT

INTRODUCTION

This report reviews the technical execution of the Tactical Environmental Data Services (TEDServices) in the context of Fleet Battle Experiment – Kilo (FBE-K). The report includes a comprehensive description of TEDServices features executed in FBE-K. Also detailed are high-level TEDServices concepts and software components as well as operational concepts and specific data flow scenarios.

TEDServices extends the Tactical Environmental Data Server (TEDS) into the era of Net Centric Warfare, Sea Power-21, FORCEnet, TaskForce Web, and the Navy Enterprise Portal (NEP). It does so by means of a new Web-based Service architecture and the Oceanographer of the Navy's (N096) Operational Concept 2002. TEDServices provides a Data-Oriented Service that supports the management and bi-directional transport of meteorological, oceanographic and environmental information. TEDS' original Relational Database Management System (RDBMS) architecture has been replaced with a lightweight, forward-deployed data cache. This data cache offers Warfighters, Meteorology and Oceanography (MetOc) professionals, tactical decision aids (TDAs)/applications and weapons systems immediate access to the Virtual Natural Environment (VNE), a 4-dimensional representation of the User defined battle-space environment. TEDServices Clients use a MetOc data order process to subscribe to relevant data. During development, the design tenets of TEDServices included: Data Transport (to reduce bandwidth use), Data Management (to simplify data ordering and forwarded deployed data administration), Data Representation (implementation of a unified Geospatial and Time Coordinate Process), and DoD Joint Interoperability (supporting standards defined by the Joint MetOc Interoperability Board).

TEDServices was designed to enable the realization of the Oceanographer of the Navy's Operation Concept (N096 OpCon). Under this OpCon, MetOc Production Centers, Centers of Expertise, and Domain Authorities deliver authenticated data and products in the form of the "MetOc Answer" to Warfighters based on their unique, relevant, operational needs. TEDServices supports this operational concept through data brokering services, data ordering processes, an application programmer's interface and an efficient, scaleable common data transport format.

TEDServices serves as the primary Fleet repository and source of Meteorology and Oceanography (MetOc) data. TEDServices provides data for numerous applications including the Naval Integrated Tactical Environmental Subsystem II Object-Oriented Re-design (NITES-II OOR) software series, the Common Undersea Picture (CUP), a variety of TDAs, and any other application that requires access to up-to-date, relevant MetOc and environmental data.

TEDServices fills a critical DoD requirement for standardized MetOc databases and extraction routines. As the DoD continues to move into the network centric warfare philosophy of the 21st century, this state-of-the-art system provides weapons systems, warfighting TDAs, and the MetOc professional with a common geospatial and temporal information source and forward-deployed assets. TEDServices also provides a data path back to Production Centers, Domain Authorities, and Centers of Expertise for on-scene remote observations of various MetOc data elements. For the first time, complete collaborative planning can be conducted with the satisfaction of knowing that all participants are using the same

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datasets. This fully upgradeable, scaleable, plug-and-play architecture is the culmination of years of intensive research and development by numerous government scientists at the Naval Research Laboratory (NRL), the Naval Undersea Warfare Center (NUWC), and civilian contractors.

TEDServices is configured to support four conceptual components for the bi-directional flow of data. These components, illustrated in Figure 1, are defined by the N096 OpCon (as modified by the FBE-K Concept of Operation - CONOP):

1. **Production Center** (PC). This component produces Numerical Weather & Ocean Prediction (NW&OP) data by assimilating global In-Situ data. Examples of production centers include FNMOC, NAVO, AFWA and other Allied organizations.

2. **Domain Authority** (DA). The Domain Authority uses NW&OP within an expert knowledge context to derive the global "MetOc Answer" that is populated within its VNE. A DA can be co-located within a Production Center. Defined domains include the following:

   - Space
   - Atmosphere
   - Ocean Surface
   - Water Column
   - Ocean Bottom
   - Littoral
   - Terrain

3. **Center of Expertise** (CoE). The Center of Expertise is the subject matter expert (SME) for MetOc effect on missions (Strike, Under Sea Warfare, Special Operations Forces, etc). The CoE uses data from the Domain Authority VNEs, as well as non-MetOc Auxiliary data sources, to refine the Domain Authority MetOc answer and produce specific data parameters and products. CoEs may be defined for either a tactical focus or tactical area of interest (AOI) and can be co-located within a Production Center or Domain Authority.

4. **Remote User (RU).** A Remote User can be an ashore, afloat or mobile consumer of MetOc Answers and/or CoE Products. A RU is represented by the Warfighter, Weapons System, or MetOc Professional. The RU orders data from the DA VNE and the CoE Products DataStore. Received data and products are stored in a Local VNE or DataStore. An RU can be co-located within a Production Center, Domain Authority, or Center of Expertise.

5. **Rapid Environmental Assessment (REA).** The REA component provides assimilation of Through-the-Sensor (TTS) In-Situ data to update key parameters in the Local VNE. In-Situ data is also passed back to Production Centers for incorporation into future model runs.

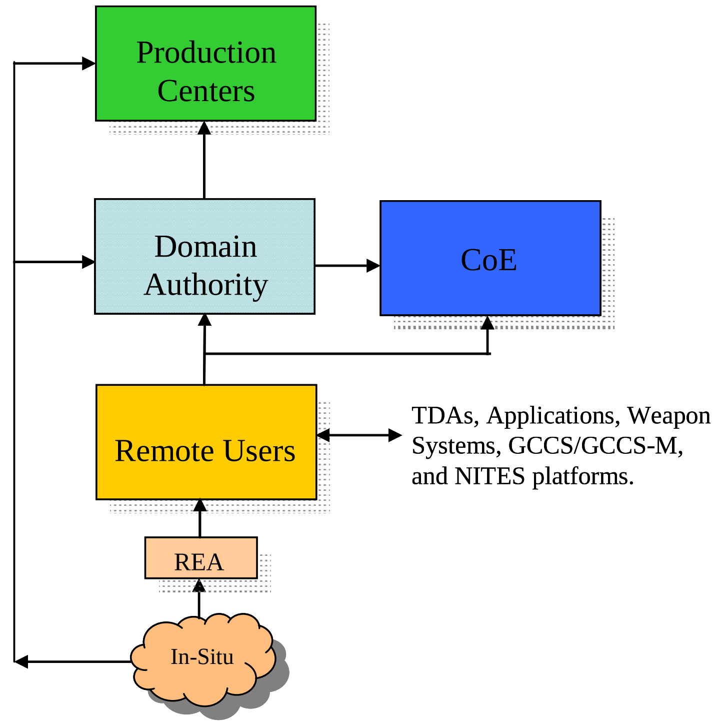

Fig. 1 - N096 OpCon conceptual components

TEDSERVICES TECHNOLOGY

Services and Interfaces

All of the previously described N096 OpCon conceptual components house or use TEDServices software technologies to facilitate the local representation, and bi-directional transport of data. Within the TEDServices dialect, these technologies are defined as Technology Services and Interfaces. Services are embodied within a TEDServices GateWay, while Interfaces are defined as:

- The TEDServices Data Browser, which can be invoked through a web browser.
- The TEDServices Application Program Interface (API), which provides methods for subscribing to, as well as querying for and extracting, data and products.
- The TEDServices Data Ordering Client, which is a Java-based Graphical User Interface providing support to legacy systems.

TEDServices GateWay

The TEDServices GateWay is a scaleable, platform independent, Java-based software process that resides on a web server, implemented in a many-to-many network topology paradigm. The TEDServices GateWay facilitates the communications between users/applications and multiple data sources/formats. It supports bi-directional communications (i.e. data requests to/from PCs, CoEs, and Domain Authorities) and the transport of In-Situ observations. TEDServices GateWays communicate within the topology using a "publish and subscribe" paradigm that ensures the delivery of relevant forward deployed data to the end-user.

There is ideally one TEDServices GateWay per platform or location. This TEDServices GateWay serves all users and applications at that platform or location. This obviates the need for multiple reach backs for the same data by multiple users. Obviating this type of reach back serves to reduce bandwidth usage.

The GateWay supports NIPRNET and SIPRNET using a standard http(s) communication protocol over port 80 (443). No special firewall modifications are necessary for SIPRNET deployments. The TEDServices GateWay software components are built around the Apache Web Server and the Tomcat Servlet Engine. Since the GateWay supports bi-directional communication through the Apache Web Server, the machine on which the GateWay resides must be connected and exposed to the wide-area network in order to allow service requests to reach the Web Server.

TEDServices Technology Services

A TEDServices GateWay is composed of several TEDServices technology services. The key services of the TEDServices software, whose relationships are shown in Figure 2, are the Local DataBroker (LDB), GateWay, Interface Support, Local DataStore and Local VNE. The TEDServices software is Java-based, providing for platform portability.

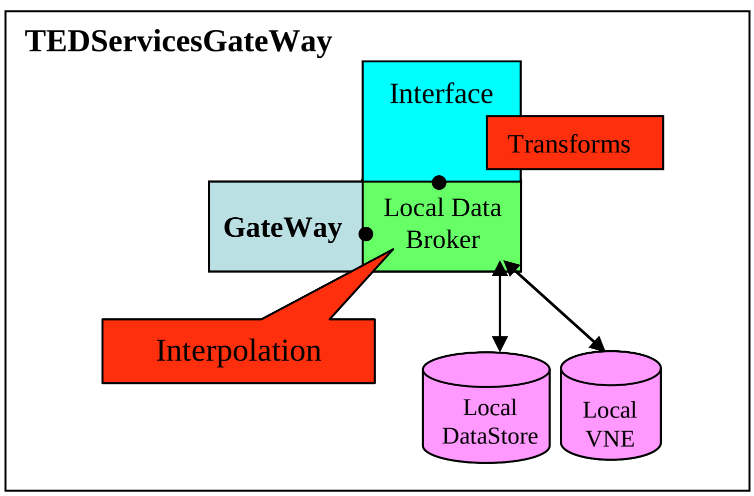

Fig. 2 – TEDServices technology components within a TEDServices GateWay

The LDB initiates and manages most G2G communications for the bi-directional flow of data between TEDServices GateWays. This communication management mitigates redundant data requests and also cancels updates of unused data. The LDB is likewise responsible for writing and reading data to and from the Local DataStore and Local VNE. In addition, the LDB manages Discrete Mission Based Data Requests (DMBDR) from Remote User Client Applications (RUCA). A MetOc data order process allows data requests to be aligned with relevant mission specific packages and platforms. This reduces the likelihood of requests for data that are not essential to a particular task. It also offers a means of simplifying training.

Direct application program interface (API) support is provided to RUCAs such as NITES-II OOR, by means of a Java Application Programmer Interface (API). An indirect application program interface is delivered through the use of a Data Ordering Client (DOC). While the functionality of these two interfaces remain essentially the same, the API provides a direct program-to-program interface, while the DOC allows a loose coupling application strategy with physical file output delivered to a user-defined data directory. DOC support was demonstrated in FBE-K by PC-Interactive Multi-sensor Analysis Training (PC-IMAT).

The GateWay component manages communication aspects that are not supervised by the LDB, such as the wire portion of the guaranteed data delivery mechanism. This component also encapsulates the software that streamlines the process of integrating data from heterogeneous sources to a Common Transport Format (CTF). This CTF assures a uniform datum, uniform projection and universal time coordinate. A CTF for all data types within TEDServices simplifies format transformations to end-users and is a significant factor for fostering interoperability.

TEDServices uses Object-Oriented cache software to persist the Local DataStore and Local VNE on disk. This software provides transactional management and multi-user access to the data and products in the DataStore and VNE.

TEDServices Components and the N096 OpCon

Each of the N096 OpCon components contains exactly one access point to TEDServices. This access point is the TEDServices GateWay. Each TEDServices GateWay is configured to initialize specific parameters by area of interest (AOI). For FBE-K, the parameters and AOI were known in advance. Operationally post-FBE-K, authorized users are able to initialize parameters and AOI on demand.

TEDServices Conceptual Data Flow

As shown in Figure 3, the GateWay component continuously imports raw data delivered to the PC TEDServices GateWay and then hands the data to the LDB for storage. This raw data consists of numerical weather and ocean prediction products such as the Coupled Ocean/Atmospheric Mesoscale Prediction System (COAMPS), the Navy’s Operational Global Atmospheric Prediction System Model (NOGAPS), and the Modular Ocean Data Assimilation System (MODAS). The raw data is immediately converted to Common Transport Format (CTF), which is then serialized to disk in the CTF DiskStore, and also placed in the Global DataStore. When data is imported into the DataStore and CTF DiskStore, the PC is then ready to receive Data Requests (subscriptions) from Domain Authorities (TEDServices GateWays).

The DA’s Init Data Request (IDR) subscribes the DA to the Production Center for all relevant PC parameters with worldwide or limited, specific coverage. After fulfilling the IDR, the PC pushes new data to the DA GateWay as new data becomes available. The PC continues to push to the DA until the subscription is cancelled. This pre-stages data at the DA for the DA VNE process. This is illustrated in Figure 3.

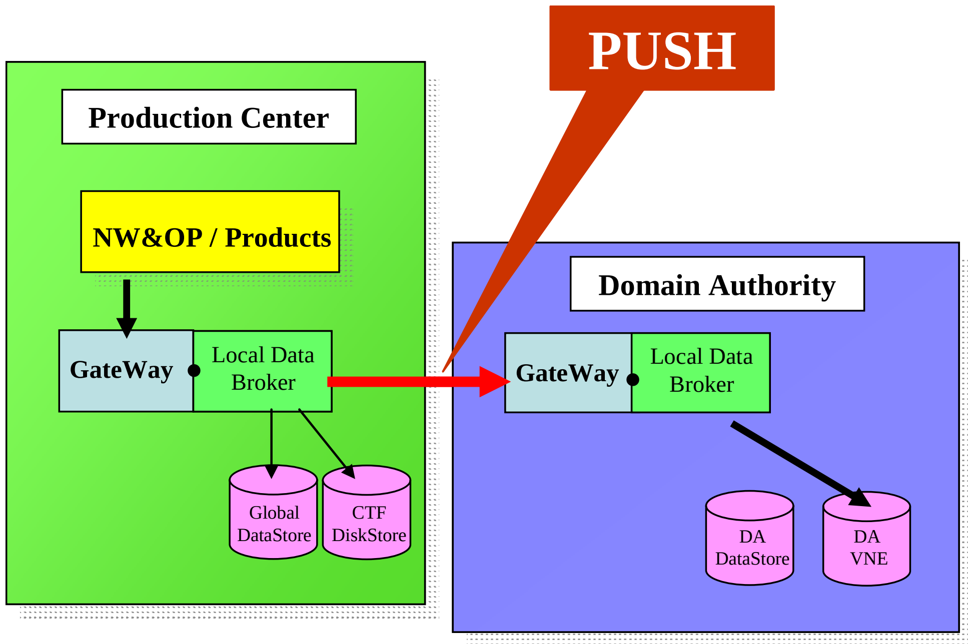

Fig. 3 – PC to DA data push

The CoE's IDR accomplishes a similar subscription. After the DA LDB fulfills the CoE's IDR, the DA LDB pushes new data to the CoE as new data becomes available. Data is pushed from the DA as forecast event times (taus) are completed. This is demonstrated in Figure 4.

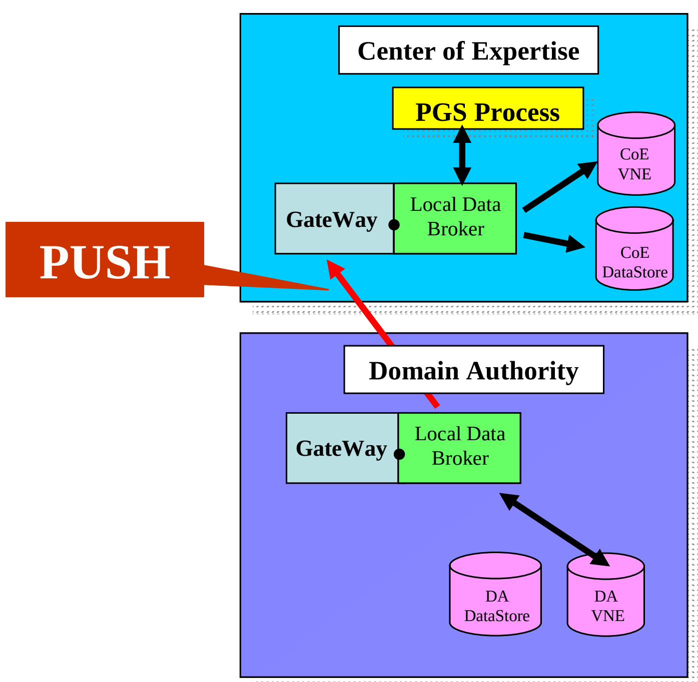

Fig. 4 – DA data push to CoE

The RU similarly places an IDR with the DA and CoE. After the DA/CoE LDB fulfills the RU's IDR, the DA and CoE LDBs push new data to the RU when new data becomes available. This is represented in Figure 5.

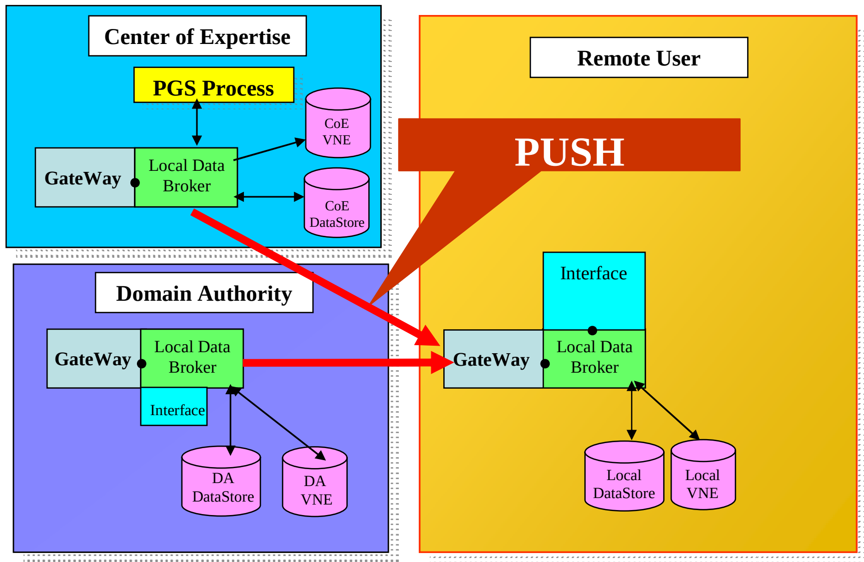

Fig. 5 – Data push to the Remote User GateWay

The end-to-end data conceptual data flow for FBE-K is depicted in Figure 6.

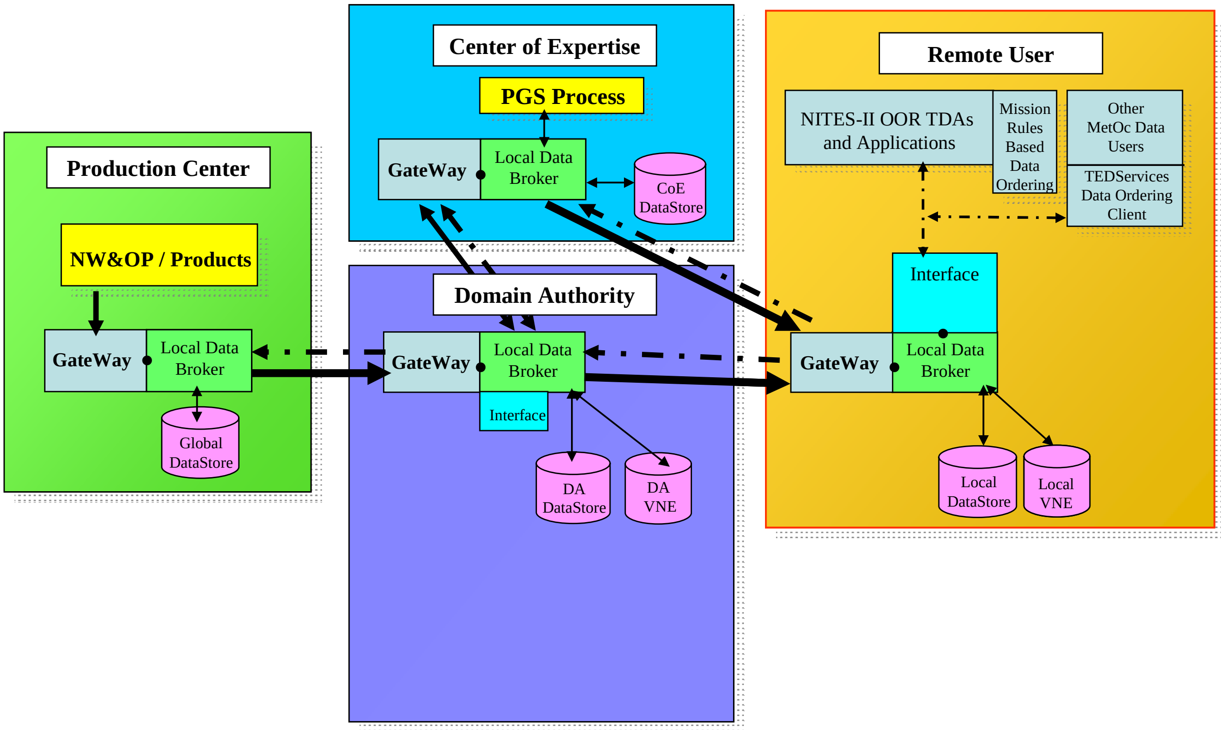

Fig. 6 – End-to-end data flow

TEDSERVICES AND FLEET BATTLE EXPERIMENT-KILO

TEDServices FBE-K Execution Objectives

TEDServices had a number of improvement objectives inherent in its design. Among these were to simplify the data and product ordering process, to automate the data and product delivery process, to reduce bandwidth usage, and to achieve minimum-effort data management and reliable transport systems. These aims were reached through the implementation of the Common Transport Format (CTF) described previously, implementation of a dynamic packet compression (LPAC), and development of Resumable Object Streams (ROS). The CTF enables movement of relevant data bi-directionally between PCs, DAs, CoEs and the RU. The common format makes LPAC feasible. ROS allows the resumption of a broken G2G communication session (not FTP) at the byte level and was developed by NRL-SSC (Code 7440).

Data management was yet another goal for improvement of TEDServices. The intent here was to simplify data ordering and provide the MetOc answer locally. This objective was achieved through the LDB, which operated to mitigate multiple “reach-back” data requests for the same parameter/product. The LDB assured that data relevant to specific missions was ordered for delivery.

Table 1 summarizes the TEDServices execution objectives for each of the TEDServices technologies executed in FBE-K. Appropriate data was collected during the execution of FBE-K, which enabled performance measurements to be made.

Table 1 – TEDServices Execution Objectives

Technology	**Assessment Metric**
LPAC	Compare data sizes to other favored compression schemes.
ROS	Measure savings in transmissions sizes in broken communications sessions.
CASP	Demonstrate seamless exchange of application state through stream serialized Java objects.

Specific Consumer Applications

The data consumers (TDAs/Applications) served by TEDServices during FBE-K are shown in Table 2 below. NITES-II OOR and JMV were serviced through the TEDServices Java API. PC-IMAT was served through the TEDServices Data Ordering Client.

Also note that TEDServices transformed NPMOC-Yoko JMV generated Ordnance Employment Fields (OEF) depictions into SHAPE files. These SHAPE files were transported to the USS Blue Ridge for incorporation into the Area Air Defense Commander System (AADCS). This was the first time that MetOc products had been introduced into AADCS.

For more details on the OEF program, please refer to the NPMOC Yokosuka - TANDEM THRUST 03**,** Fleet Battle Experiment-Kilo Post-Exercise Report.

Table 2 – Consumer Applications Served Data by TEDServices

Consumers	COAMPS	NOGAPS	MODAS	NCOM	CASP	OEF
NITES- II OOR	X	X		X	X	
PC-IMAT			X	X		
JMV					X	
JMV / AADCS						X

TEDServices Deployment in FBE-K

Presented in Figure 7 are the participants in FBE-K, categorized by the conceptual component they represent in the N096 OpCon. On the SIPRNET, each of the Production Centers, Domain Authorities, Centers of Expertise and Remote Users housed a TEDServices GateWay. In Figure 7, bulleted text is used to indicate applications that used TEDServices during FBE-K and/or products that were created using TEDServices data.

Applications that used TEDServices included Joint MetOc Viewer (JMV), NITES-II OOR, PC-IMAT via the TEDServices Data Ordering Client and OASES via the TEDServices Data Browser. The USS Blue Ridge was originally planned to house a TEDServices GateWay during the demonstration; however, the GateWay at the Fleet MetOc Advanced Concepts Lab (FMACL) in San Diego acted in place of the Blue Ridge.

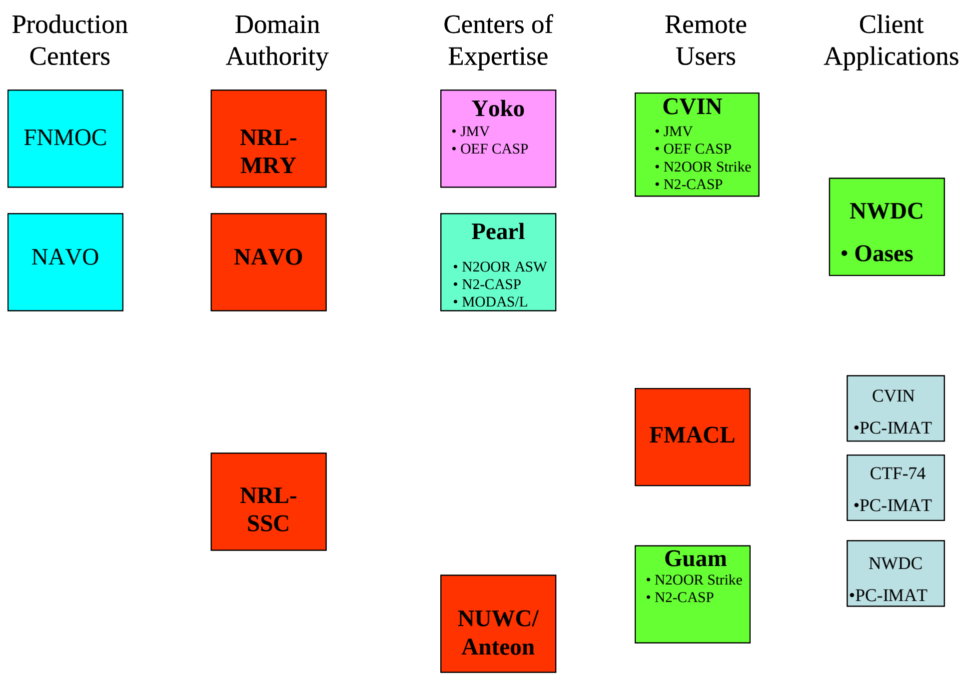

Fig. 7 – TEDServices GateWay and software deployment for FBE-K

TEDServices – Collaborative Application Sharing Process (CASP)

To support a distributed, collaborative process, TEDServices demonstrated the use of a unique feature called the Collaborative Application Sharing Process (CASP). While CASP is an inherent feature of TEDServices, it is an outgrowth of the legacy SIIP/NITES-II Product Generation and Transmission (PG&T) capability. CASP enables application users to share the "status/state" of their applications between subscribing consumers.

CASP was demonstrated by NPMOC-Yoko (Figure 8), and NITES-II OOR (Figure 9).

NPMOC Yoko used CASP to transport OEF objects between the Center and the USS Carl Vinson. The Center would produce an initial forecast depiction (12-36 hours), and the USS Vinson would collaborate with a local 0-12 hour forecast. This process continued throughout FBE-K.

As represented in Figure 9, CASP was tested using the NITES-II OOR application at GUAM and PEARL. The application state of NITES-II OOR at PEARL and GUAM were shared using CASP. These CASP objects were created using atmospheric and oceanographic data available in the forward deployed cache on the local TEDServices GateWays.

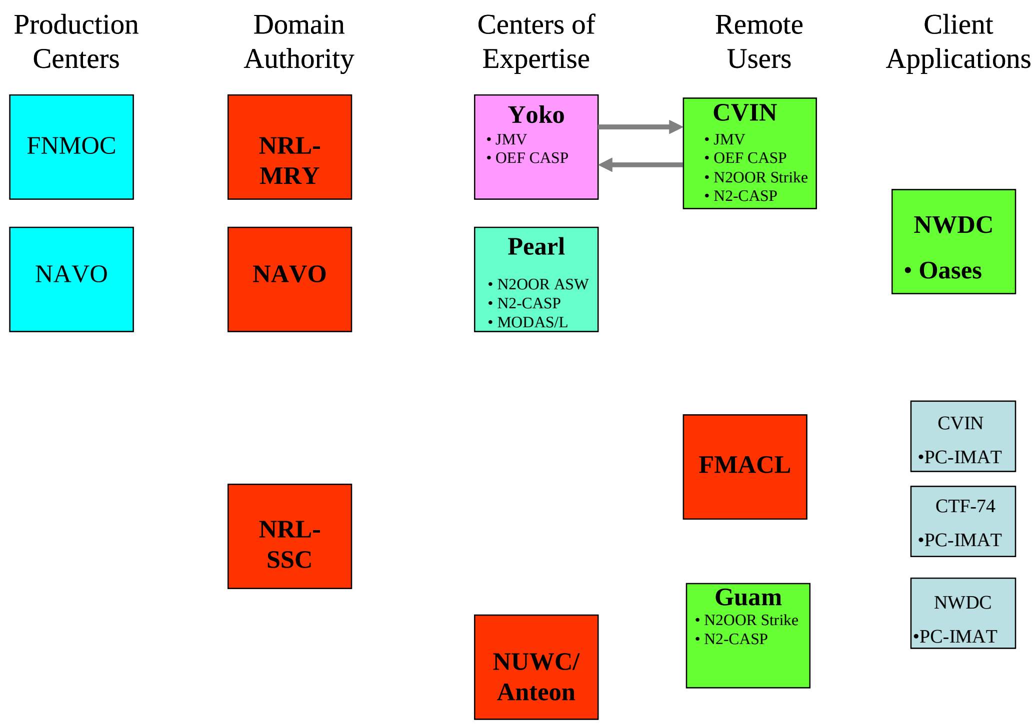

Fig. 8 – Ordnance employment bi-directional product flow using CASP

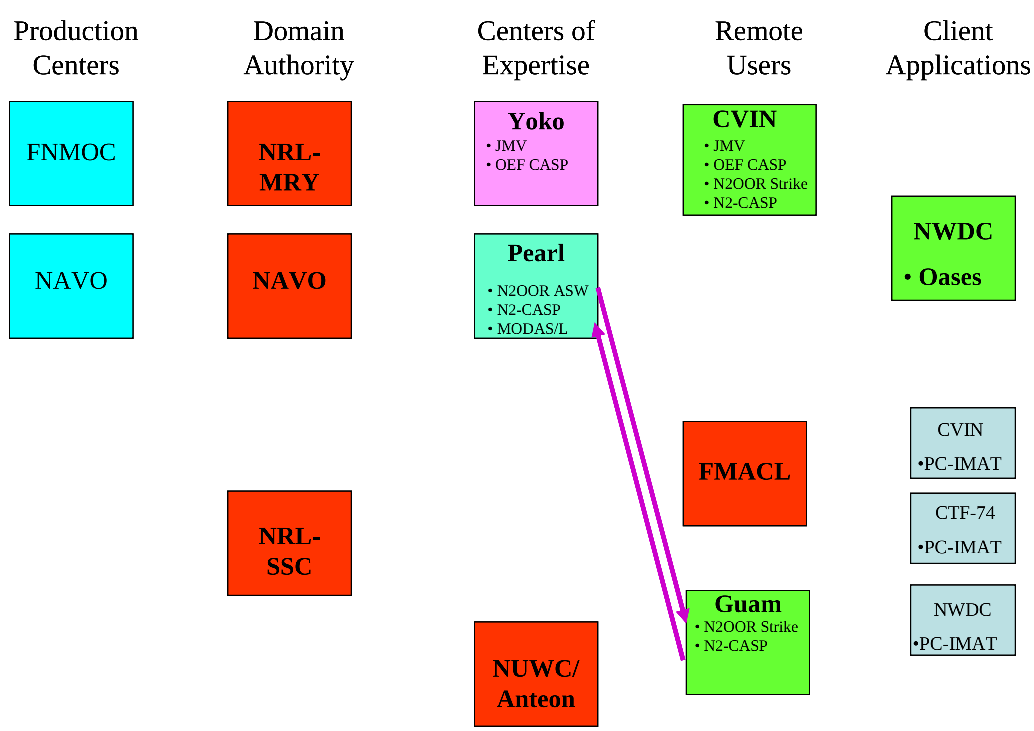

Fig. 9 – NITES-II Collaborative Application Sharing Process flow

TEDServices Data Browser

Figure 10 shows how NWDC used the TEDServices Data Browser to extract the data from several TEDServices GateWays. This data was then passed to Ocean, Atmosphere, Space, Environmental Services (OASES) for distribution to a Modeling & Simulation federation.

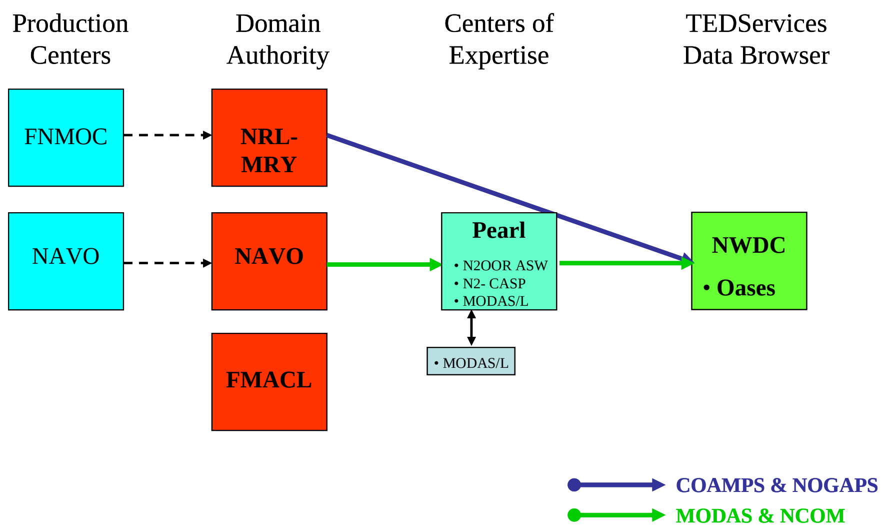

Fig. 10 – OASES support

Planned Topology

Figure 11 below illustrates the planned, automated oceanographic data flow during FBE-K. The Fleet MetOc Advanced Concepts Lab (FMACL) was used to simulate a TEDServices GateWay that would have been deployed aboard the USS Blue Ridge. Details of the diagram follow.

Within the NAVO SIPRNET, NCOM and MODAS data were FTP'd to the NAVO TEDServices GateWay machine, where it was automatically ingested into the VNE. Data for specific parameters were then pushed to other TEDServices GateWays (Pearl Harbor) based on data subscriptions for particular parameters and areas of interest. Upon receipt of the data at the Pearl Harbor TEDServices GateWay, staff at Pearl used the parameters as first guess fields, along with Expendable Bathythermographs (XBTs), to run the MODAS LITE model. The value-added data was then pushed to other TEDServices GateWays (Carl Vinson, FMACL, GUAM and NUWC) based on their data subscriptions for particular parameters and areas of interest.

Several Remote User Client Applications accessed the data on the TEDServices GateWays. These client applications included NITES II OOR, PC-IMAT Data Ordering Client and the TEDServices Data Browser.

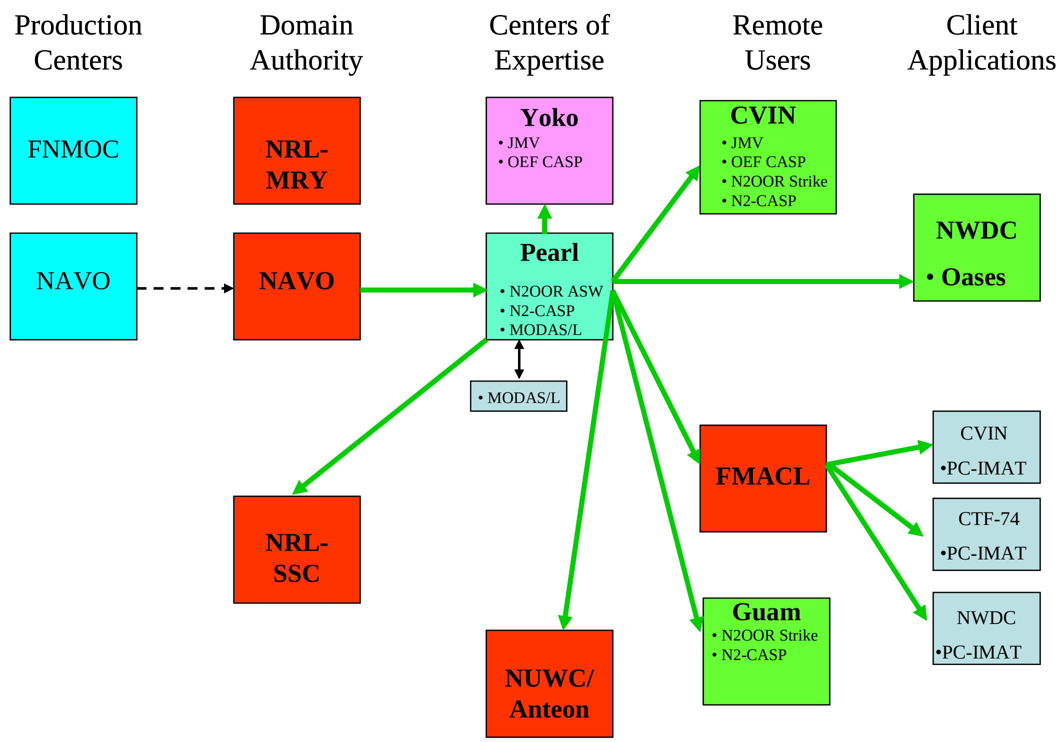

Fig. 11 – Planned MODAS and NCOM model data distribution

Adjusted Topology

During the second day of FBE-K there was a critical hardware failure of the GateWay machine in Pearl Harbor. Data flow was immediately redirected to other TEDServices GateWays while a replacement machine was routed to Pearl. This redirect lasted approximately a day and a half. The NRL-SSC core TEDServices development team provided remote support for this redirection of TEDServices GateWays. The redirected data flow is illustrated in the Figure 12. In the future, redirection will be automatic with the selection of up to three (3) sources for data.

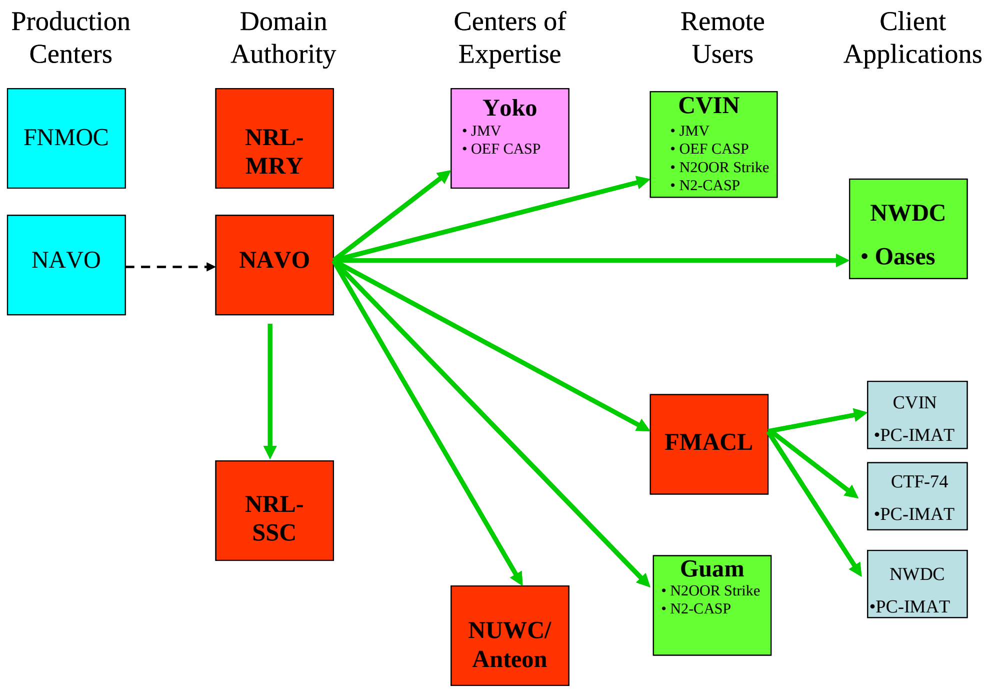

Fig. 12 – Adjusted MODAS and NCOM model data distribution mid FBE-K due to hardware failure at Pearl Harbor

TEDSERVICES METRICS DURING FLEET BATTLE EXPERIMENT-KILO

This section provides performance metrics specific to the deployment of TEDServices Gateways and software in FBE-K. The following metrics trace MODAS and NCOM model data in an end-to-end data flow that occurred during FBE-K.

NAVO Ingest Metrics

All data ingested at Production Centers occurred in an automated fashion. Using scripts, chron jobs or scheduled services, data was FTP'd to the TEDServices GateWay where it was automatically ingested. No human interaction was required for the ingest process to occur. An ingest process was continually running in the background on the TEDServices GateWay. The process ingested data files that it found and then slept for a configurable amount of time. The process then awoke and looked for any new files to process. This describes the basic ingest loop that automated the model data ingest.

Table 3 describes the amount of oceanographic model data ingested at the NAVO TEDServices GateWay during FBE-K and the resulting size of the compressed, stored data.

Table 3 – Size of Ingested and Stored Model Data at NAVO TEDServices GateWay

Model Data Ingested	**Daily Model Data Received at NAVO TEDServices GateWay (approx.)**	**Cumulative Model Data Received at NAVO TEDServices GateWay (approx.)**	**Cumulative NAVO TEDServices GateWay VNE Size (approx.)**
MODAS	31.91 MB	255.26 MB	91.20 MB
NCOM	369.91 MB	2,959.25 MB	1160.00 MB
Totals	**401.82 MB**	**3,214.51 MB**	**1,251.20 MB**

MODAS Data

MODAS data was FTP'd to the NAVO TEDServices GateWay once per day for the length of FBE-K (eight days). The model data contained three parameters (salinity, sound speed and sea temperature) and covered an area of interest specified by the following bounding box:

South Latitude: 7.0
West Longitude: 133.0
North Latitude: 30.0
East Longitude: 157.0

The amount of raw data FTP'd per day is listed in Table 3 in the column titled “Daily Model Data Received at NAVO TEDServices GateWay.” Per day, the raw model data totaled 32 MB. The amount of MODAS data ingested at the NAVO TEDServices GateWay during FBE-K totaled 255 MB. The ingest of MODAS raw data contributed 11.4 MB to the VNE on a daily basis resulting in a VNE that totaled of 91 MB at the completion of FBE-K. The shrinkage of the ingested data from 255MB to 91 MB can be attributed to the LPAC compression utilized.

NCOM Data

NAVO produced NCOM data was FTP'd to the NAVO TEDServices GateWay once per day for the length of FBE-K. The model data contained six parameters (salinity, sound speed, sea temperature, water level elevation, u component and v component) and covered the same area of interest listed for the MODAS data.

The amount of NCOM raw data FTP'd per day is listed in Table 3 in the column titled “Daily Model Data Received at NAVO TEDServices GateWay.” Per day, the raw model data totaled ~370 MB. The amount of NCOM data ingested at the NAVO TEDServices GateWay during FBE-K totaled almost 3 GB. The ingest of NCOM raw data, contributed 145 MB to the VNE on a daily basis resulting in a VNE that totaled slightly over 1 GB at the completion of FBE-K. The shrinkage of the ingested data from 3 GB to 1 GB can be attributed to the LPAC compression utilized.

NAVO Transmission Details

Originally, per the FBE-K topology, NAVO was scheduled to transmit data only to Pearl Harbor and NRL-SSC. Pearl, acting as a Domain Authority, would then transmit data to Yoko, NUWC, FMACL, CVIN and GUAM based on their subscriptions. However, due to a catastrophic hardware failure at PEARL on the 5th day of FBE-K, data subscriptions for Yoko, NUWC, FMACL, CVIN and GUAM were rerouted directly to NAVO for approximately a day and a half.

The equipment failure at Pearl was rectified on the second to last day of FBE-K. The data subscriptions for Yoko, NUWC, FMACL, CVIN and GUAM were cancelled at NAVO and re-established at PEARL.

Table 4 describes which GateWays were subscribed to receive oceanographic model data from the NAVO TEDServices GateWay and how the NAVO TEDServices GateWay data transmissions were distributed among the subscribing parties (NRL-SSC, Pearl Harbor, Yoko, NUWC, FMACL, CVIN and GUAM TEDServices GateWays).

Table 4 – Transmissions From the NAVO TEDServices GateWay to Other TEDServices GateWays

Receiving TEDServices GateWay	**Amount Received**
Pearl Harbor	554.69 MB
NRL-SSC	214.10 MB
YOKO	29.05 MB
NUWC	19.88 MB
FMACL	17.72 MB
CVIN	12.40 MB
GUAM	4.30 MB
NAVO Total Transmissions	**852.14 MB**

The TEDServices GateWays located at YOKO, NUWC, FMACL, CVIN and GUAM were subscribed to the NAVO TEDServices GateWay for approximately two days and for smaller Areas of Interest (AOI) than Pearl Harbor and NRL-SSC. The amount of data to be transmitted to the YOKO, NUWC, FMACL, CVIN GateWays was much less than what was to be transmitted to Pearl Harbor and NRL-SSC. However, NAVO should have successfully transmitted the same amount of data to each of the YOKO, NUWC, FMACL, CVIN GateWays as they were subscribed to the same smaller AOI for the same parameters. The amount of oceanographic data that NAVO should have successfully transmitted to each of these Gateways over the two-day period was approximately 29.05 MB, the amount that Yoko received. Network connectivity issues that lasted for extended periods of time prevented this from happening.

Resumable Object Streams (ROS)

A delivery guarantee mechanism was implemented in TEDServices and used during FBE-K. This delivery mechanism is Resumable Object Streams (ROS). ROS is a mechanism that guarantees delivery of transmission data within a specified maximum try time interval. That is, ROS will continue attempting to deliver transmission data for the time interval specified. If the transmission data cannot be delivered within the specified time, the transmission is then dropped. During FBE-K, ROS was configured so that it would try to complete a transmission for up to two hours. According to these numbers, that was not long enough.

FBE-K drove home the point that network centric warfare is not a perfect world. Loss of network connectivity for extended periods of time must be considered. In the course of FBE-K, the following incidents occurred that affected connectivity for intervals of more than two hours at time. Each of these incidents occurred in different locations.

- On an afloat platform, the local SIPRNET went down.
- A network cable was unplugged from a TEDServices GateWay in order to share with another machine.
- A cleaning crew accidentally turned off the power to a TEDServices GateWay.
- A catastrophic hardware failure occurred on one of the TEDServices GateWays.

This exercise highlighted that particular attention must be paid to development for an automated system. ROS was sufficient for a window of opportunity - if the network went down or the receiving server went down, ROS guaranteed delivery within a two hour window.

After the configurable retry limit was exceeded, ROS timed out and dropped the transmission. Something more was needed in addition to this retry interval. The exercise helped in identifying a weak point in the delivery process. This has been fixed within the TEDServices Local Data Broker. After a timeout, the LDB puts data to be sent to the remote gateway into a queue and periodically monitors the network for restored connectivity. The transmitting GateWay will resume transmission of data (using ROS) once the receiving GateWay comes back on-line. In the latter case, only the most current data is sent.

The version of ROS used in FBE-K worked well for network hiccups and network outages that were shorter than two hours. During FBE-K, eight cases were recorded where network connectivity was lost in mid data transmit. When network connectivity was regained, ROS continued the data transmission at the point where it was interrupted. It did not retransmit the entire data transmission, only the portion of the data that was not transmitted initially. In other cases, ROS guaranteed delivery by establishing initial connectivity prior to sending data as the remote TEDServices GateWay was unreachable upon initial attempt to transmit data.

NAVO Transmission Details

In Table 4, the Pearl Harbor TEDServices GateWay is listed as receiving data from the NAVO TEDServices GateWay. Pearl Harbor received NCOM and MODAS data for six days instead of eight due to the hardware failure at Pearl Harbor. The numbers reflected for Pearl Harbor in the above table indicate that all appropriate data was transmitted from NAVO and received by Pearl Harbor. NRL-SSC is also listed in the above table as receiving data from NAVO. However NRL-SSC received data from NAVO for only two days, from the time of the hardware failure at Pearl through the end of FBE-K.

Figure 13 is a scatter plot that compares the sizes of the NAVO TEDServices GateWay transmissions and amount of time required to successfully transmit the data. This plot includes transmissions of oceanographic data for a total 711 transmissions. While some of the transmit time variations can be attributed to network latencies, it is reasonable to suggest that the transmissions in the plot that required longer than 2.5 minutes to transmit are the cases where ROS was guaranteeing the delivery of data within a specified maximum try time interval. That is ROS continued attempting to deliver transmission data for the time interval specified and encountered network connectivity issues.

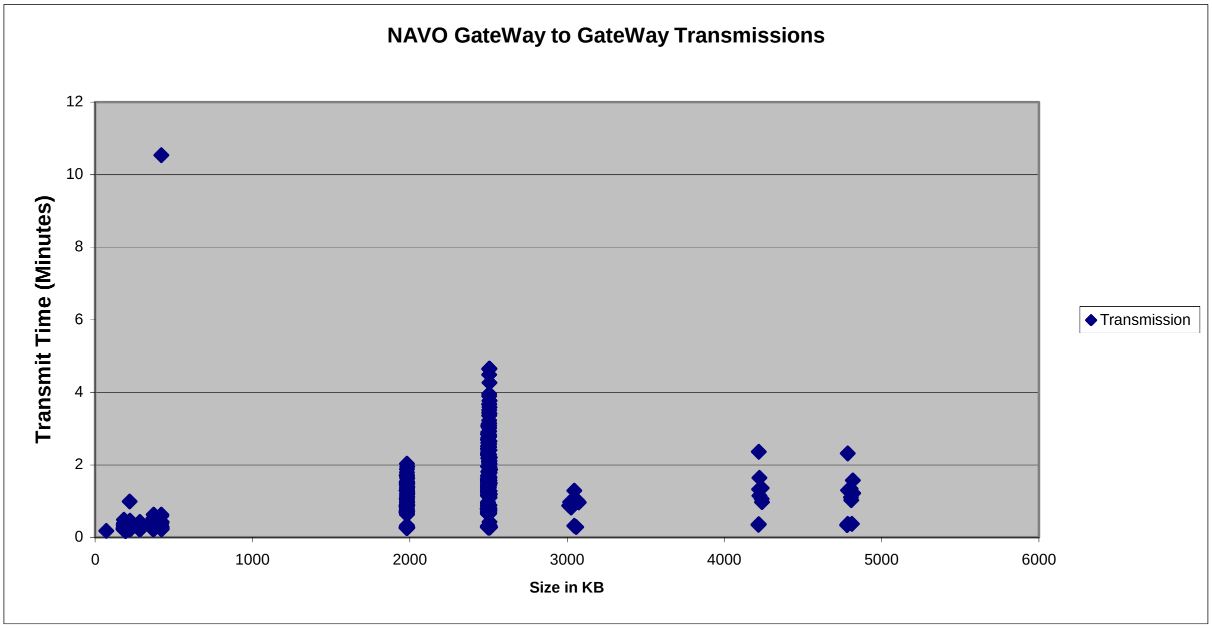

Fig. 13 – NAVO TEDServices GateWay transmissions

There were forty-two transmissions that took longer than 2.5 minutes to successfully transmit. Note in particular the transmission on the upper left of the graph. The transmission was about 500 KB and took ten minutes to guarantee delivery. This transmission would most likely have been dropped without ROS.

ROS is a built-in feature of all GateWay-to-GateWay transmissions. Therefore, ROS was utilized in each successful transmission. The amount of ROS assistance provided was dependent upon the connectivity issue encountered. If no connectivity issue was encountered, then minimal ROS assistance was provided.

Of the G2G transmissions where ROS guaranteed delivery, most required that ROS assist in establishing initial connectivity prior to sending data as the remote TEDServices GateWay was unreachable upon initial attempt to transmit data. Some of the G2G transmissions lost connectivity in mid data transmit. In those cases, ROS regained connectivity and transmitted the remainder of the data to the remote TEDServices GateWay. There were eight of these incidents during FBE-K. In the case of NAVO NCOM data, the transmission could have been as large as 6.6 MB. Whether there was no initial connectivity or whether connectivity was lost in the course of transmission, without ROS, the transmissions would have been dropped.

Pearl Harbor Transmission Details

Upon receipt of the oceanographic data from the NAVO TEDServices GateWay, staff at Pearl Harbor used parameters obtained from the local TEDServices GateWay as first guess fields when running the MODAS LITE model. The value-added data was then pushed to other TEDServices GateWays (Carl Vinson, FMACL, GUAM and NUWC) based on their data subscriptions for particular parameters and areas of interest.

Table 5 describes how the Pearl Harbor TEDServices GateWay transmissions were distributed among Yoko, NUWC, FMACL, CVIN and GUAM TEDServices GateWays. This table includes oceanographic and atmospheric data transmissions.

Table 5 – Transmissions From the Pearl Harbor TEDServices GateWay to Other TEDServices GateWays

Receiving TEDServices GateWay	**Amount Received**
NRL-SSC	466.2 MB
GUAM	53.5 MB
NUWC	50.6 MB
FMACL	48.9 MB
CVIN	28.9 MB
YOKO	11.35 MB
Pearl Harbor Total Transmissions	**659.45 MB**

As the Pearl Harbor TEDServices GateWay had a hardware failure that lasted two days, the numbers above reflect approximately 5 to 6 days worth of data transmissions from Pearl Harbor TEDServices GateWay to other TEDServices GateWays. The amount of data transmitted to NRL-SSC was much larger than the amount of data transmitted to the other GateWays. This is because NRL-SSC was subscribed to a larger AOI than the other TEDServices GateWays.

The above numbers seem to indicate that by allowing subscriptions for different subsets of available data, bandwidth is better utilized by transmitting only the required data. However, because there were dropped transmissions as mentioned in the previous section, it is more accurate to illustrate the amount of savings using a controlled environment. This will be done in the upcoming section titled “Pipeline Management.”

Figure 14 is a scatter plot that compares the sizes of the Pearl Harbor TEDServices GateWay transmissions and amount of time required to successfully transmit the data. This plot includes transmissions of oceanographic and atmospheric data for a total 5463 transmissions. On the left side of the plot, note that there are some small transmissions that took just over 20 minutes. While some of the transmit time variations can be attributed to network latencies, it is reasonable to suggest transmissions taking more than 2.5 minutes are the transmissions where ROS assistance was required in order for the data to be delivered. Note the many 1 KB transmissions that required ten minutes or more. ROS continued attempting to deliver transmission data for the time interval specified and encountered network connectivity issues. Within the 10 - 25 minutes, ROS was able to gain initial connectivity or regain broken connectivity to deliver the data.

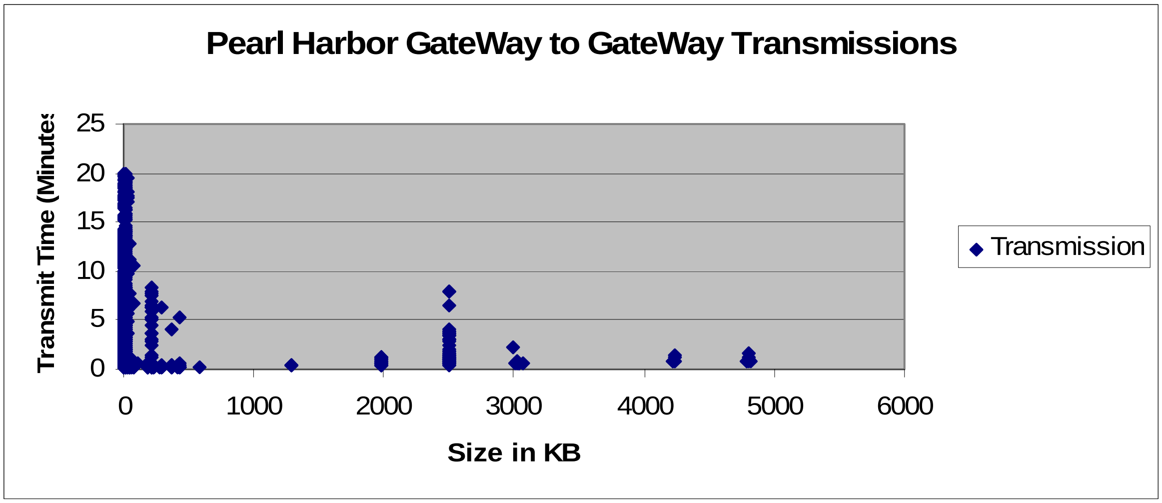

Fig. 14 – Pearl Harbor TEDServices GateWay to GateWay transmissions

Pipeline Management

TEDServices managed the amount of data passed through the SIPRNET communications “pipe” by several methods. LPAC compressed the data prior to transmitting it and ROS mitigated the need to resend data through the pipe. In addition, the TEDServices architecture and implementation gave the ability to trim data as it traveled across the pipeline from the Production Center to the Warfighter. This reduction of data was accomplished using a phased pipeline management approach. This phased approach allowed data that traveled across the pipe to be trimmed at two key points as illustrated in Figure 15.

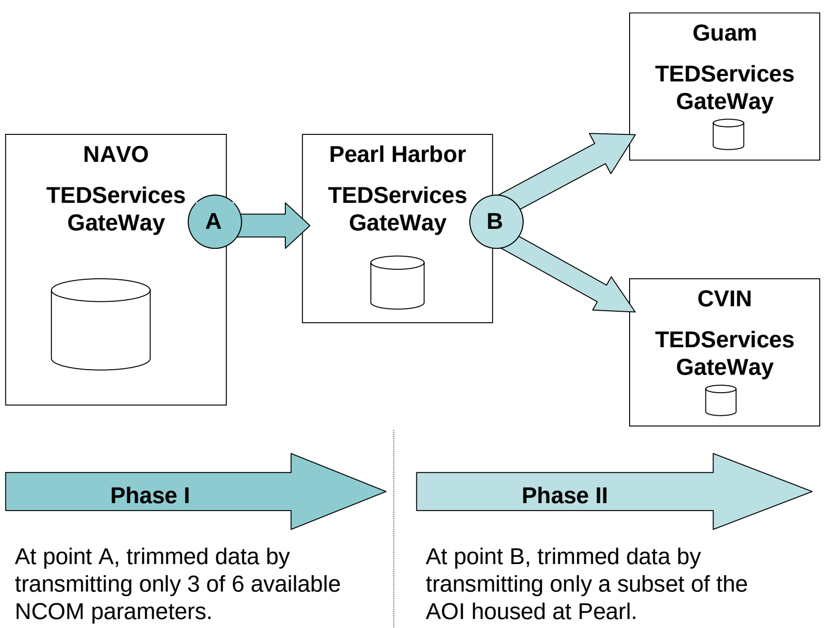

Fig. 15 – Phased reduction of data transmissions

NAVO ingested three MODAS parameters and six NCOM parameters. Pearl Harbor subscribed to all three MODAS parameters, but only three of the six NCOM parameters. The six NCOM parameters that were available included:

- salinity
- sound velocity
- sea temperature
- water level elevation
- v component
- u component

The three parameters that were subscribed to included:

- salinity
- sound velocity
- sea temperature

One run of NCOM data, which contained the six parameters, would have produced transmissions from NAVO to Pearl Harbor that totaled 145 MB in size. Instead, by allowing only the needed parameters to be transmitted, the NCOM transmissions totaled only 87 MB in size.

This represents bandwidth savings at point A. Note that savings is "per run" of the NCOM model. As a by product, this allowed for a smaller amount of data to be stored at the Pearl Harbor TEDServices GateWay. Notice how the data stores shrink in size from left to right in Figure 15.

Pearl Harbor subscribed to and received three NCOM parameters from NAVO. The Carl Vinson and GUAM subscribed to Pearl Harbor for all three available NCOM parameters but for a smaller area of interest than what was available on the Pearl Harbor TEDServices GateWay.

The area available included:

South Latitude: 7.0
West Longitude: 133.0
North Latitude: 30.0
East Longitude: 157.0

The area subscribed to included:

South Latitude: 11.0
West Longitude: 143.0
North Latitude: 17.0
East Longitude: 151.0

Transmissions from the Pearl Harbor TEDServices GateWay to the GUAM or CVIN TEDServices GateWay would have totaled 87 MB in size with the total available AOI. Instead, by allowing only the needed AOI to be transmitted, the NCOM transmissions totaled only 7.7 MB in size. This represents bandwidth savings at point B. This also is a "per model run" savings.

During FBE-K, the data trimming occurred by parameter at point A and by AOI at point B; however, trimming by parameter or by AOI can occur at either location and it can occur simultaneously at a single location. Simultaneous trimming would result in maximum savings of bandwidth usage.

The numbers presented above are the most accurate way to represent the pipeline management. Actual numbers from FBE-K would not present data from which inferences could be made. This is due to hardware failures and other circumstances beyond control which were previously described. The above numbers were obtained by capturing the raw NCOM model data from one day during FBE-K, then running the subscription/transmission process in a controlled environment.

Client Applications

The TEDServices GateWays at FMACL, CVIN and GUAM did not have any clients in the form of TEDServices GateWays; therefore, no G2G transmission details were available to capture. These GateWays had clients in the form TDAs as suggested in Figure 11.

For example, the NITES II OOR TDA was utilized to access the oceanographic data that was received on the local TEDServices GateWay at GUAM and CVIN. In addition, data was obtained from the FMACL TEDServices GateWay for the PC-IMAT client application via the TEDServices Data Ordering Client. The latter is a Java-based GUI providing support to legacy systems. OASES used the TEDServices Data Browser to obtain oceanographic data from the Pearl Harbor TEDServices GateWay and atmospheric data from NRL MRY. OASES extracted the data in netCDF file format. After the Pearl Harbor hardware failure, OASES was redirected to the NAVO TEDServices GateWay.

SUMMARY

During FBE-K, TEDServices successfully demonstrated a number of capabilities. One was to reduce the number and size of data transmissions. This capability was made possible via publish-and-subscribe mechanisms, the use of LPAC to compress data transmissions and the implementation of Resumable Object Streams. A phased pipeline management approach minimized movement of unnecessary parameters to GateWay locations. Also demonstrated was the automated end-to-end data flow, which reduced the amount of time spent acquiring data by the staff at PC, DA, COE and Remote User locations. The seamless exchange of application state through stream serialized Java objects, made possible in the form of CASP, was also demonstrated.

This report outlines just a few of the design goals that were met. Overall, the FBE-K demonstration of TEDServices satisfied the original goals of data transport, data management, data representation and data transformation. TEDServices successfully showed reduction in bandwidth use and forward deployment of the MetOc answer through simplified data ordering. Data was normalized under one single geospatial and temporal time coordinate reference model within the CTF. Multiple end-user required formats were supported (SHAPE, draw, netCDF, Java object). A seamless exporting of operational data to M&S users was accomplished.

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